Burgner & Putnam

High potential tests of oils

Electrical Engineering

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HIGH POTENTIAL TESTS OF OILS

BY

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AND
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THESIS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

HARLEY THOMPSON BURGNER and WILLIAM JAMES PUTNAM

ENTITLED HIGH POTENTIAL TESTS OF OILS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Electrical Engineering

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Instructor in Charge

APPROVED: E m Berg

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INTRODUCTION

In all high tension work the question of insulation is the one which limits the voltage. In transmission lines it becomes a problem of allowing sufficient space between the conductor and grounds or other wires, but for inside work, as in switches, transformers, and other apparatus, some other means of insulation must be used. In switch work an insulation of high dielectric strength is needed, and one which has the quality that an arc once established through it is not easily maintained, and the insulation is not appreciably damaged. For transformers and apparatus of a similar nature, the insulation must not only have high dielectric strength, but must also afford a means of cooling the apparatus.

For these purposes mineral oil seems to have more of the above mentioned qualities than any other dielectric. It is known to have a high dielectric strength, moves freely by convection so as to convey heat readily, and, in case of discharge through it, will quickly extinguish the arc and renew the insulation.

On account of these qualities oil has come into general use in high voltage work, and all manufacturers of high tension apparatus now have especially prepared mineral oils which they advise for use in their apparatus.

OBJECT.

Originally the object of this thesis was to investigate the insulative strength of various kinds of oil, by means of the high tension spark, and to assertain the effect of various conditions to which the oil might be subjected, such as changes of temperature and pressure, or the introduction of moisture or other foreign matter held either in suspension or by chemical union.

Due to the fact, however, that the presence of numerous other variables prevented an accurate examination of the ones mentioned above, the object of these tests necessarily changed to an investigation of the methods of testing.

DESCRIPTION OF APPARATUS.

The main apparatus used in these tests is shown complete in Plate I. It consists essentially of a cast iron base B, 15" x 10" x 1", above which is a triangular brass plate P, 3/16" thick, supported by three fiber rods 1" in diameter and 17" long. To the iron base is fixed a square brass plate A, 4" on a side, with a threaded boss C, Plate IV, centrally located, upon which may be placed the brass base D. This latter base supports the glass testing tube G, in which the sample of oil to be tested is placed, and is threaded to receive the lower terminal T. The base D enters the bottom of the glass tube and is made oil tight by means of a lock nut N and leather washers, as shown in the detailed drawing on Plate VI.

The micrometer head H, which is shown in detail on Plate VII, and in position on Plate I, is supported by the plate P and is adjustable

to a central position over the lower terminal T. The inner sleeve S which carries the upper terminal T' and moves vertically, is held from turning with the dial E, by means of the arm F which is guided by a slot J in the framework of the head. This device was resorted to in order to minimize the error due to turning of the sleeve S. A side play of 1/16" at the end of the arm F will cause only .0001" vertical movement of thr sleeve and upper terminal. The dial E carries the nut of the micrometer screw which has twenty threads per inch. This nut is split and threaded at the upper end and has a knurled nut K, Plate VII, with a tapered thread, by which any wear or play in the micrometer thread may be taken up.

The dial proper is divided into fifty parts, thus reading to thousandths of an inch, and these main divisions are divided into halves. A secondary dial L, Plate III, also graduated to read in thousandths, is just beneath the main dial and is held in any position by the thumb screw M, so that it may be used as an adjustable zero. The terminal is firmly held in the sleeve S by the thumb screw N so that it may be loosened and raised out of the way for placing the test tube on the base C.

These testing tubes are simply plain graduate tubes 12" high and 2" internal diameter so thar it takes about one pint of oil for each test. In starting a test, the zero is adjusted by bringing down the upper terminal until contact is made, as is shown by ringing a bell circuit through the terminals. The upper connection is made at the binding post O, Plate III, while the lower one is made at the post R, Plate IV.

Plate I shows the apparatus with the first terminal used in

position. These consist of 1/2" balls on 1/4" rods. Plate II was taken with the new terminals in position. Plate III shows the upper part of the apparatus, while Plate IV gives the details of the base and lower terminals.

Plate V shows, rather indistinctly, the device arranged for changing the gap while the high voltage was on. The clamp C' is made with fingers which grip the knurled nut on the micrometer dial. To this clamp is fastened a long glass rod R' running up into a split spindle S' and held there by the clamp and wing nut N'. This spindle rotates freely in vertical bearings placed directly over the testing apparatus, and has a grooved wooden pulley P' on its upper end. A silk cord is passed twice around this pulley, to prevent slipping, and runs to an exactly similar pulley some fifteen feet distant. This latter pulley is supported like the first but has a hand wheel on the lower end of its shaft so that it may be turned by a person standing on the floor. Thus the operator is sufficiently insulated from the high voltage and turns the micrometer head as he pleases. Of course all readings must be made on the micrometer dial, simply the number of full turns being noted by the operator.

The testing voltage was taken from the high tension transformer in the University Laboratory which is rated at 10 K.W., at 60 cycles 440 to 100,000 volts. The low voltage was taken from the substation in the main laboratory, the field current of the alternator being carried down onto the board in the high tension laboratory so that the rheostats were in the same room, with the testing apparatus.

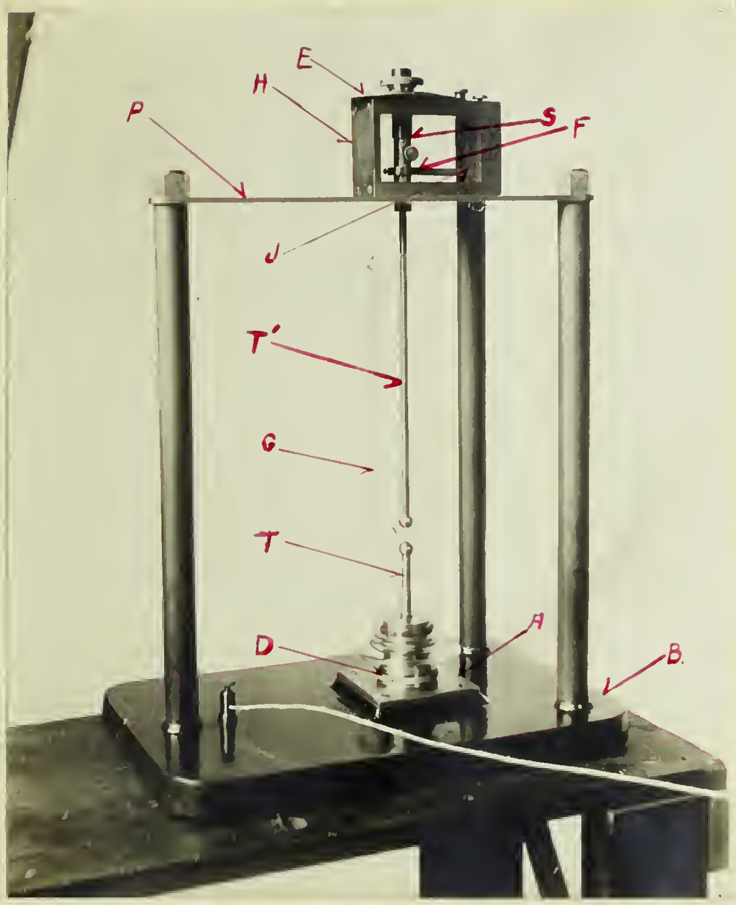


Plate I.

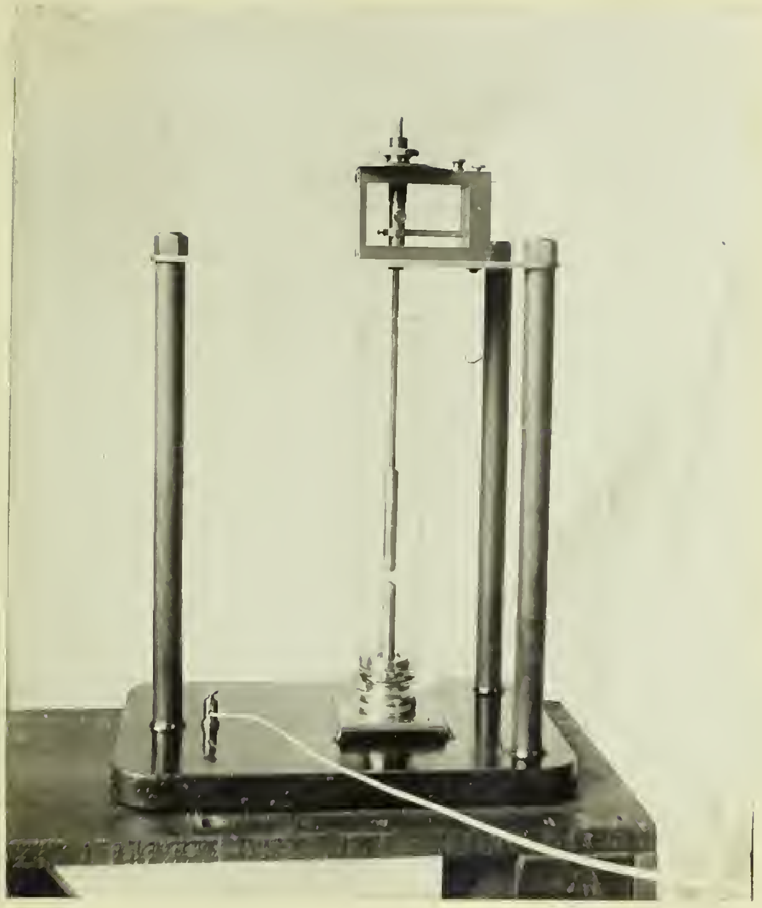


Plate II.

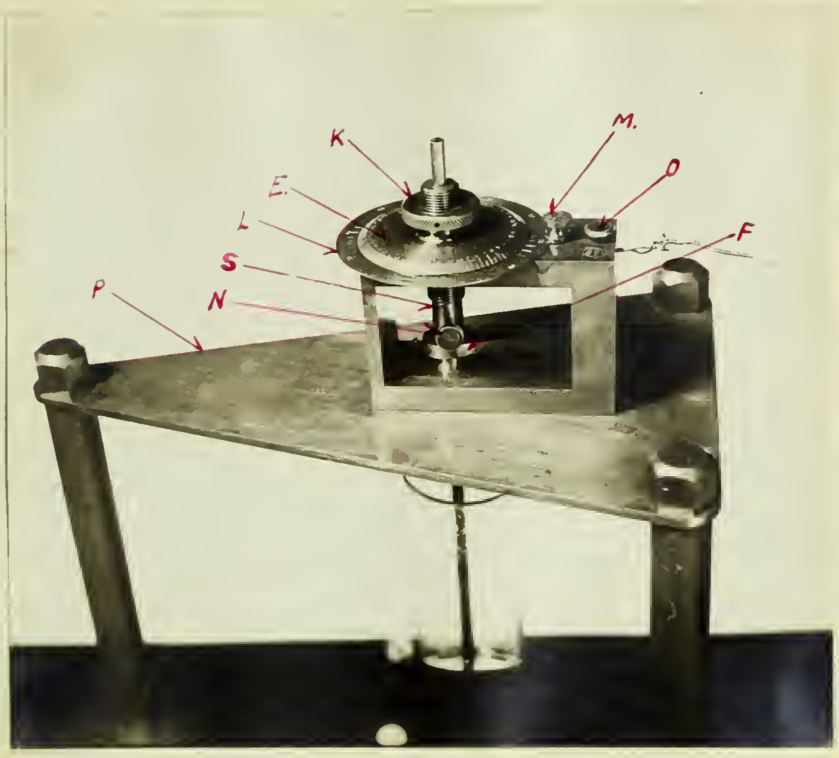


Plate III

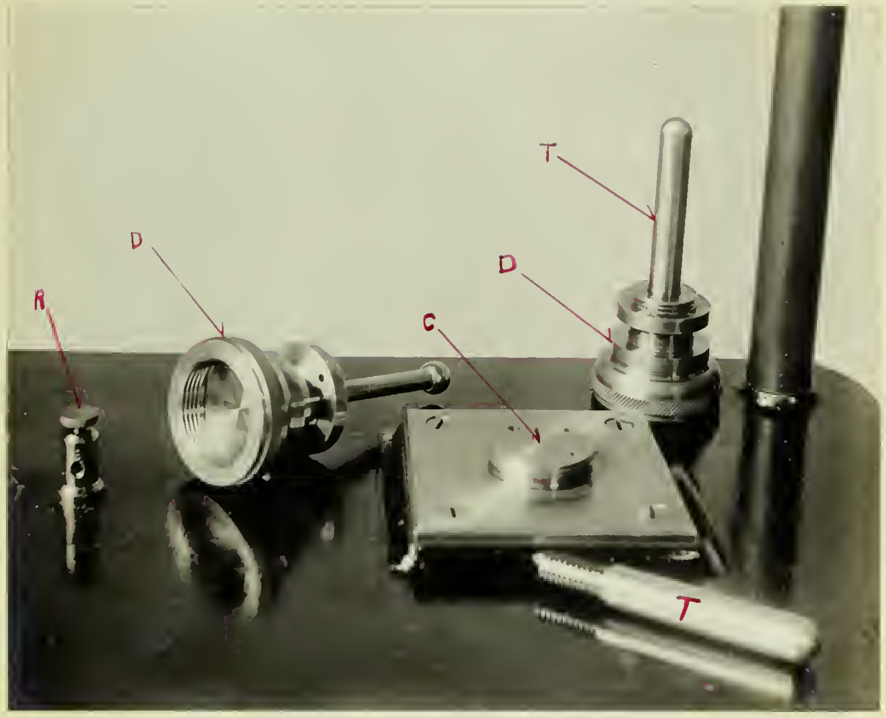


Plate IV.

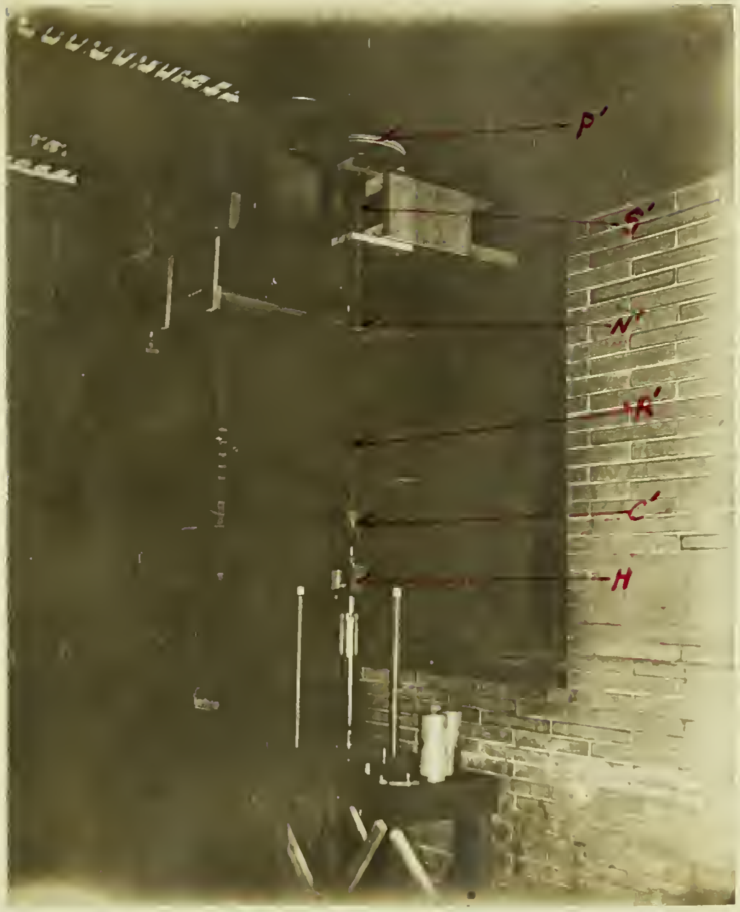


Plate V.

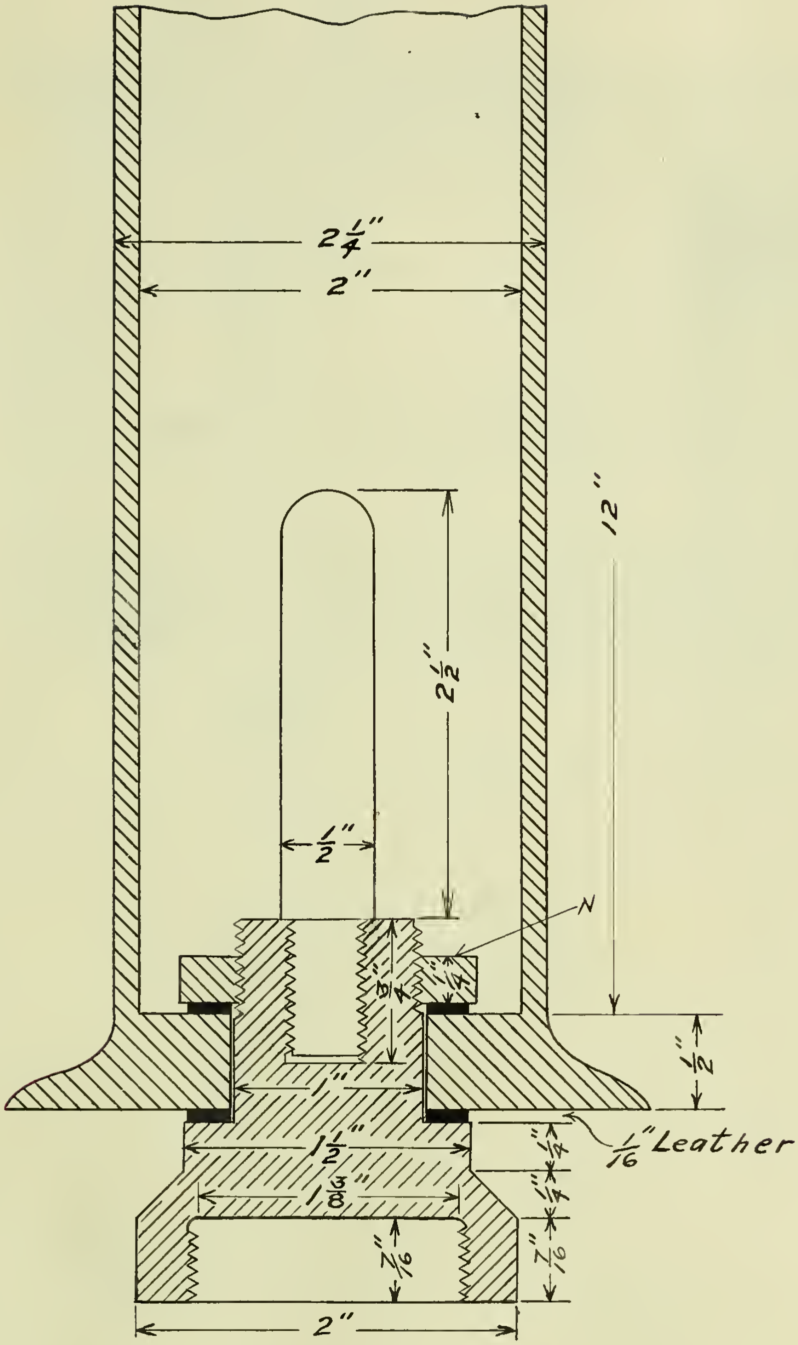


Plate VI.

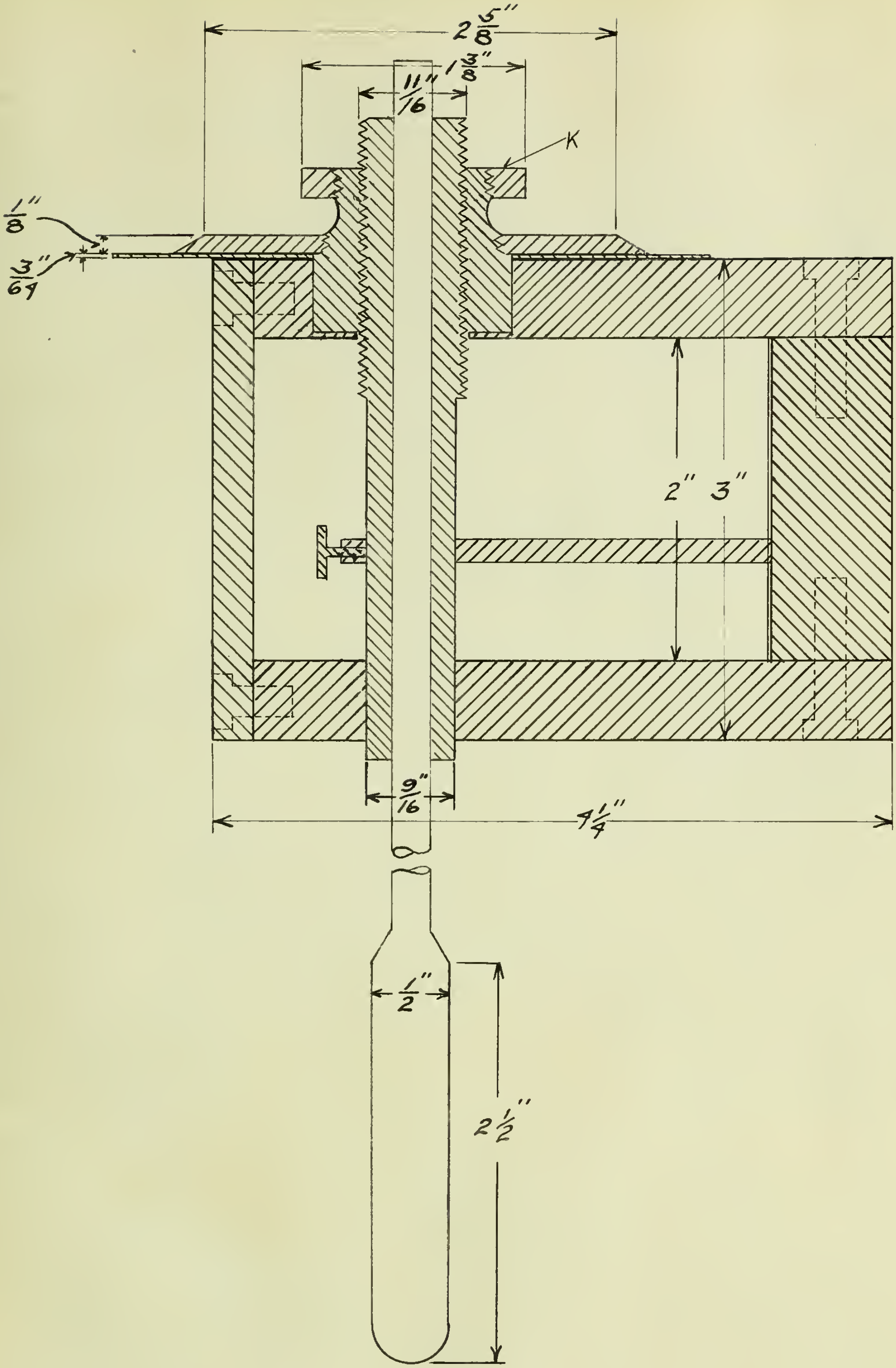


Plate VII.

DESCRIPTION OF TESTS.

As previously stated, the object of this thesis was primarily to study the effect of various conditions upon the dielectric strength of oil, the first variation chosen being that of temperature.

With this in view a preliminary test was run to make sure that uniform results could be obtained for repeated breakdowns at a constant tenperature. The first test was run with repeated breakdowns in the same sample of oil, but the results as shown in the data and on Curve Sheet No. I were extremely irregular. In running this test the spark gap was set at .20 in. and the voltage raised to breakdown by decreasing the resistance in the field of the alternator which supplied the secondary E.M.F.

In taking the readings it was noticed that the breakdown voltage depended, to a great extent, upon the speed with which the resistance was cut out. To make sure of this both extremes were tried; i.e.- the resistance was cut out very slowly in the first case, allowing the voltage to increase gradually to breakdown, while in the second, the resistance was all cut out before closing the transformer switch, causing an almost instantaneous rise of voltage.

To obviate this difficulty the device shown in Plate V was constructed so that the gap could be varied while a constant voltage was being applied to the terminals. The results obtained with this arrangement, while considerably more regular than those of the previous test, were quite irregular as shown in data and Curve Sheet No. II.

The next step was to try the effect of a higher voltage upon the

irregularity of breakdown but the tests showed thaf it was aggravated rather than dimished.

A sample of Kerosene from the High Tension Transformer was tested at 60,000 volts, whereas the Transil oil had been tested at 40,000 volts. A comparison of the results from Tests No. III and IV is shown oi Curve Sheet No. III, the points for the Kerosene being much more regular than for the Transil oil.

In the tests thus far only one base and terminal had been used, the terminal being a 1/2" ball on a 7/32" rod, held in the base by a taper fit. Another base was made, the terminal being screwed into it, and by accident the rod was turned to a diameter 1/32" larger than the one previously used.

These two bases were then used alternately in the tests to allow the carbon from the arc at breakdown to become uniformly distributed between tests, and it was noticed that the older terminal gave a lower value of voltage in each case.

A comparison of the two is shown by Tests V and VII, the latter being run with the newer base. It was then thought that the condition of contact between base and terminal caused the irregularity so the older base was tapped and its terminal threaded insuring good contact. As a result the data in Test No. VI was obtained, which, although it gave higher values than in Test No. V, was still lower than No. VII. As a further experiment the 7/32" rod was wrapped tightly with tinfoil until it was 9/32" in diameter. It was then found in Test No. VIII that higher values were obtained than with the 1/4" rod. A good comparison of the results is shown on Curve Sheet No. IV.

To go to the extreme in the size of the rod, a new upper ter-

minal and two lower ones were made having 1/2" rods with hemispherical ends.

Two Tests, No. IX and X, were then run with repeated breakdowns on the same sample to see whether or not with the new terminals, uniform results could be obtained by varying the voltage at a constant gap. It will be seen from Curve Sheet No. V that about the same irregularity as before was prevalent.

Test No. XI was run at a constant potential of 40,000 volts, the gap being decreased to breakdown. The results which are fairly uniform are shown on Curve Sheet No. VI.

Test No XII was run on a sample of Kerosene taken from the High Tension Transformer to determine the effect of repeated breakdowns upon the dielectric strength.

The voltage was held at 60,000 volts and the gap decreased to breakdown at intervals of two minutes.

As seen on Curve Sheet No. VII the gap is practically constant up to about thirty breakdowns, at which point the strength of the oil rapidly decreases.

A similar test of one hundred breakdowns was then run on the Transil oil. The results vary widely but are about the same on an average, at the end as at the beginning. The red points on Curve Sheet represent the average gap for every ten breakdowns.

DISCUSSION AND CONCLUSIONS.

The number of tests run and results obtained are limited by the time available for experimental work since most of the time was spent on the design and construction of apparatus. Some of the work, such as

drilling the holes through the bottom of the glass test tubes was very tedious and required a great deal of care. A device was also designed and constructed for obtaining a temperature range from 0°C to 100°C but lack of time prevented experiments being run with it.

The results obtained seem to lead to the following conclusions:-

First: Much more accurate and uniform results can be obtained by varying the gap at constant voltage than by varying the voltage across the fixed gap.

Second: For a given size of terminal, a 1/2" ball for instance, the size of rod leading to it materially affects the breaking voltage for a given gap, being lower for a small rod and higher as the diameter of the rod approaches that of the ball.

Third: Within certain limits the dielectric strength of the oil is not appreciably affected by the number of discharges through it.

Fourth: Kerosene gives more uniform results but weakens more quickly with repeated breakdowns than does Transil oil, and for the latter reason would be less suitable for oil switch operation where discharges are frequent.

Fifth: The reason that the Kerosene gives more uniform results is that its viscosity is less, and therefore the burned carbon from a discharge is more quickly and uniformly distributed through the oil. It was noticed with samples of Kerosene that the first break tinged the entire mass of oil almost immediately, while with the Transil oil, it colored only the portion around the terminals. Also, the Kerosene if allowed to stand a day or two after testing, deposited all the carbon at the bottom and became as clear as before, while the Transil oil, though left for weeks, still retained the carbon throughout its

volume. It was also found by testing that the Kerosene had regained its original strength while the Transil oil had not.

If it were not for the fact that Kerosene has a very low flashing point it would be by far the better oil for high tension work.

TEST NO. I. - G. E. TRANSIL OIL NO. 6

No. of Break		E	No. of Break		E
1	-	29800	17	-	26800
2	-	28200	18	-	25000
3	-	31100	19	-	24600
4	-	32300	20	-	25000
5	-	35700	21	-	34800
6	-	34100	22	-	35400
7	-	37700	23	-	32000
8	-	29600	24	-	26800
9	-	27300	25	-	41800
10	-	27300	26	-	42300
11	-	25000	27	-	34100
12	-	20400	28	-	38900
13	-	28200	29	-	29800
14	-	20900	30	-	29800
15	-	20900	31	-	30500
16	-	29800	32	-	31400

Gap = 0.20 inches

TESTS NO. II - III - IV.

G. E. TRANSIL OIL NO. 6 AND KEROSENE.

No. of Break		Gap in inches.	No. of Break		Gap in inches.	No. of Break		Gap in inches
1	-	.122	1	-	.259	1	-	.329
2	-	.121	2	-	.245	2	-	.260
3	-	.139	3	-	.313	3	-	.254
4	-	.095	4	-	.208	4	-	.254
5	-	.096	5	-	.219	5	-	.260
6	-	.100	6	-	.184.	6	-	.264
7	-	.105	7	-	.196	7	-	.279
8	-	.069	8	-	.234	8	-	.261
9	-	.102	9	-	.210	9	-	.242
10	-	.109	10	-	.284	10	-	.247
11	-	.108	11	-	.154	11	-	.249
12	-	.120	12	-	.170	12	-	.289
13	-	.086	13	-	.288	13	-	.284
14	-	.063	14	-	.193	14	-	.278
E = 20,600			15	-	.250	15	-	.278
			E = 40,000			16	-	.270
						E = 60,000		

TESTS NO. V - VI - VII - VIII.

G. E. TRANSIL OIL NO. 6

Loose Contact 7/32" rod No. of Break	E	Tight Contact 7/32" rod No. of Break	E	Tight Contact 1/4" rod No. of Break	E	Tight Contact 9/32" rod No. of Break	E
1 -	20000	1 -	23000	1 -	31000	1 -	44500
2 -	19100	2 -	23000	2 -	34100	2 -	43200
3 -	16800	3 -	23000	3 -	31800	3 -	43000
4 -	18200	4 -	23600	4 -	33200	4 -	50000

Gap = 0.25 inches.

TESTS NO. IX - X - XI.

G. E. TRANSIL NO. 6.

No. of Break	E	No. of Break	E	No. of Break	Gap in inches.
1 -	41000	1 -	32400	1 -	.187
2 -	41300	2 -	30200	2 -	.152
3 -	30000	3 -	42700	3 -	.169
4 -	47700	4 -	30000	4 -	.158
5 -	32300	5 -	29600	5 -	.163
6 -	30900	6 -	30900	6 -	.155
7 -	31800	7 -	43200	7 -	.210
8 -	32400	8 -	49000	8 -	.179
9 -	38600	9 -	36800		
Gap = 0.25 in.		Gap = 0.25 in.		E = 40,000	

TEST NO. XII. KEROSENE.

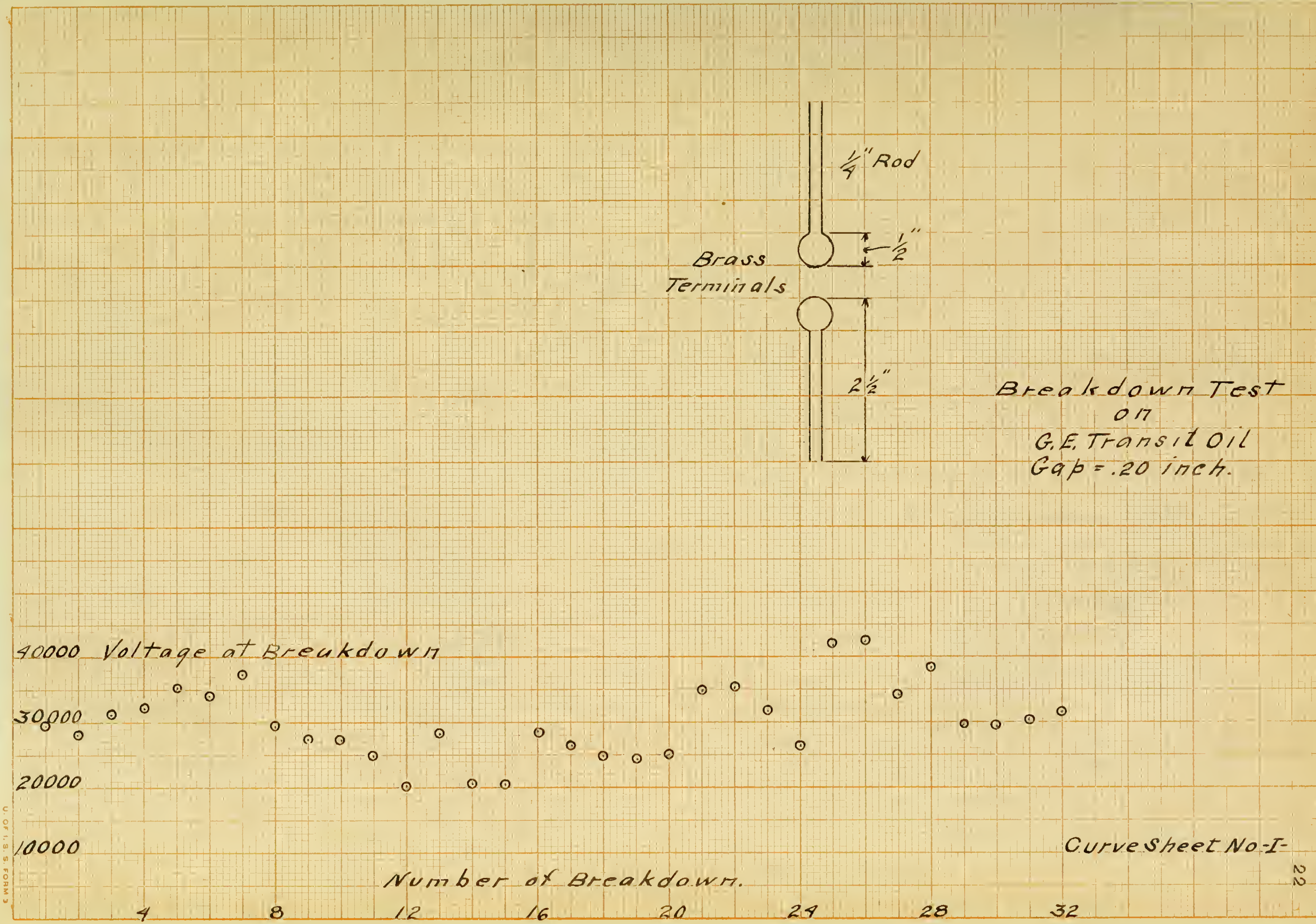
No. of Break		Gap in inches	No. of Break		Gap in inches	No. of Break		Gap in inches
1	-	.231	26	-	.251	51	-	.572
2	-	.184	27	-	.220	52	-	.685
3	-	.215	28	-	.237	53	-	.693
4	-	.219	29	-	.248	54	-	.693
5	-	.209	30	-	.242	55	-	.693
6	-	.193	31	-	.233	56	-	.682
7	-	.217	32	-	.276	57	-	.644
8	-	.178	33	-	.267	58	-	.669
9	-	.184	34	-	.297	59	-	.726
10	-	.195	35	-	.357	60	-	.730
11	-	.215	36	-	.349	61	-	.846
12	-	.244	37	-	.306	62	-	.846
13	-	.201	38	-	.360	63	-	.836
14	-	.189	39	-	.342	64	-	.840
15	-	.207	40	-	.375	65	-	.956
16	-	.225	41	-	.412	66	-	.804
17	-	.222	42	-	.490	67	-	.894
18	-	.221	43	-	.513	68	-	.833
19	-	.225	44	-	.546	69	-	.936
20	-	.207	45	-	.581	70	-	.956
21	-	.234	46	-	.568	71	-	.886
22	-	.223	47	-	.543	72	-	.869
23	-	.239	48	-	.526	73	-	.936
24	-	.220	49	-	.505	74	-	.836
25	-	.223	50	-	.541	75	-	.957

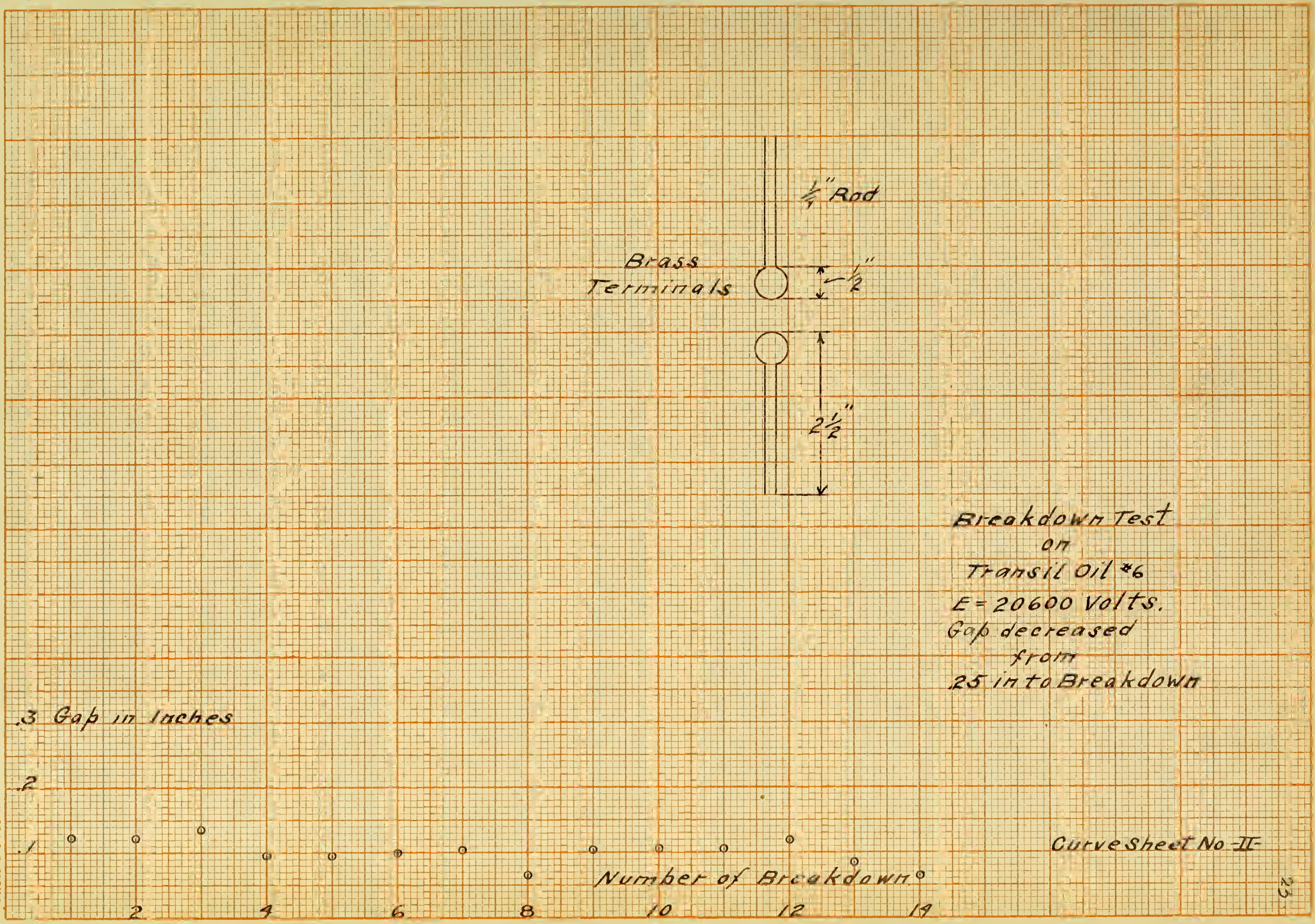
E = 60,000

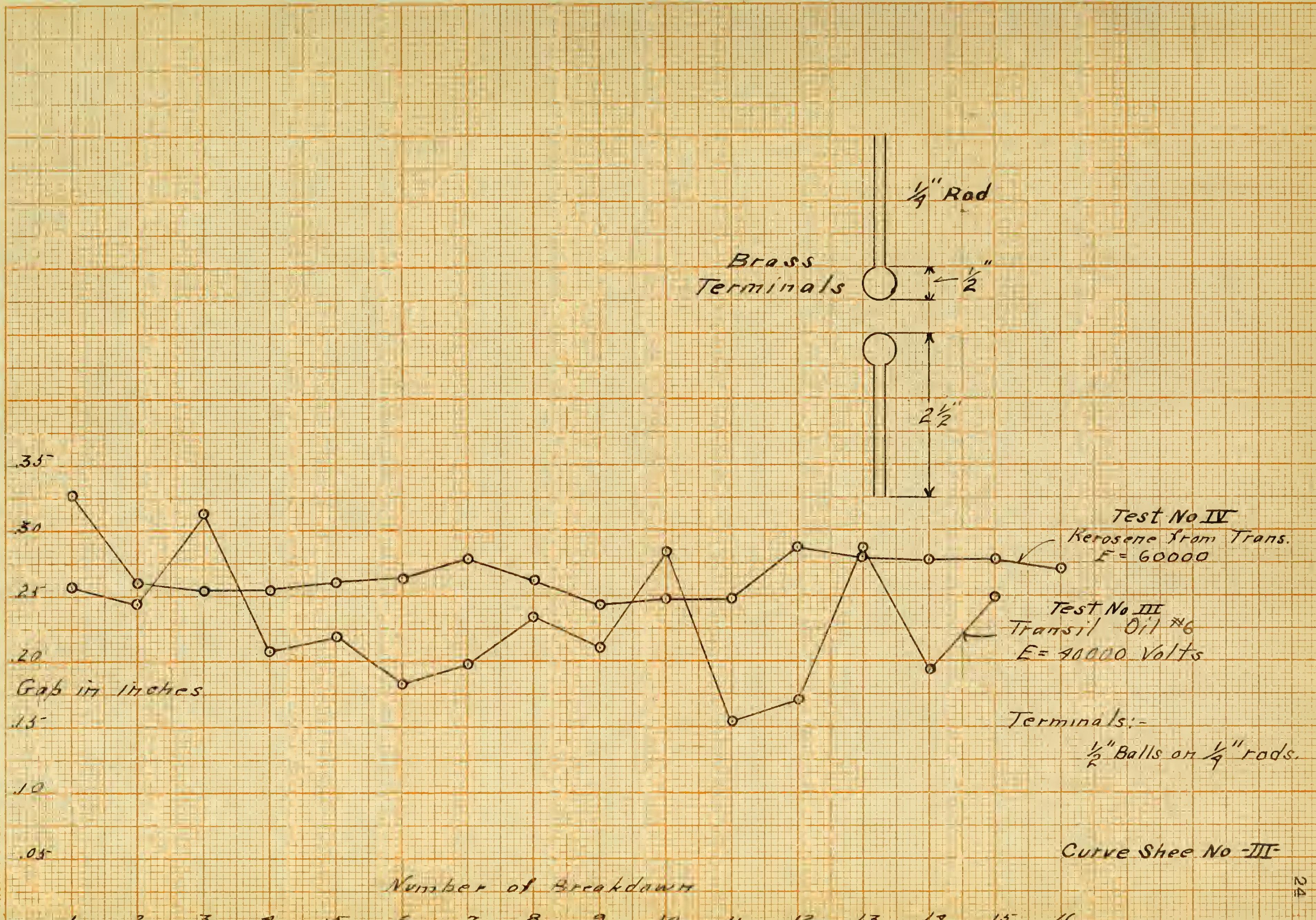
TEST NO. XIII. G. E. TRANSIL OIL NO. 6.

No. of Break	Gap in inches	No. of Break	Gap in inches	No. of Break	Gap in inches	No. of Break	Gap in inches
1	- .414	26	- .736	51	- .505	76	- .483
2	- .440	27	- .634	52	- .510	77	- .515
3	- .503	28	- .915	53	- .601	78	- .513
4	- .329	29	- .490	54	- .476	79	- .539
5	- .293	30	- .436	55	- .458	80	- .607
6	- .342	31	- .434	56	- .435	81	- .513
7	- .274	32	- .746	57	- .462	82	- .754
8	- .298	33	- .484	58	- .489	83	- .508
9	- .586	34	- .427	59	- .602	84	- .471
10	- .545	35	- .447	60	- .477	85	- .641
11	- .576	36	- .505	61	- .616	86	- .493
12	- .791	37	- .518	62	- .576	87	- .541
13	- .662	38	- .565	63	- .450	88	- .675
14	- .567	39	- .560	64	- .442	89	- .508
15	- .793	40	- .456	65	- .438	90	- .513
16	- .314	41	- .515	66	- .672	91	- .590
17	- .309	42	- .716	67	- .573	92	- .586
18	- .487	43	- .452	68	- .574	93	- .531
19	- .344	44	- .448	69	- .657	94	- .486
20	- .472	45	- .459	70	- .514	95	- .495
21	- .672	46	- .451	71	- .456	96	- .453
22	- .492	47	- .454	72	- .463	97	- .572
23	- .480	48	- .473	73	- .548	98	- .557
24	- .486	49	- .462	74	- .551	99	- .475
25	- .506	50	- .495	75	- .618	100	- .483

E = [illegible]0,000


1/4" Rod
1/2"
Brass
Terminals
2 1/2"
Breakdown Test
on
G.E. Transil Oil
Gap = .20 inch.
40000 Voltage at Breakdown
30000
20000
10000
Number of Breakdown.
4
8
12
16
20
24
28
32
Curve Sheet No-I-


1/4" Rod
Brass Terminals
1/2"
2 1/2"
Breakdown Test
on
Transil Oil #6
E = 20600 Volts.
Gap decreased
from
.25 in to Breakdown
.3 Gap in Inches
.2
.1
Number of Breakdown
2
4
6
8
10
12
14
Curve Sheet No II



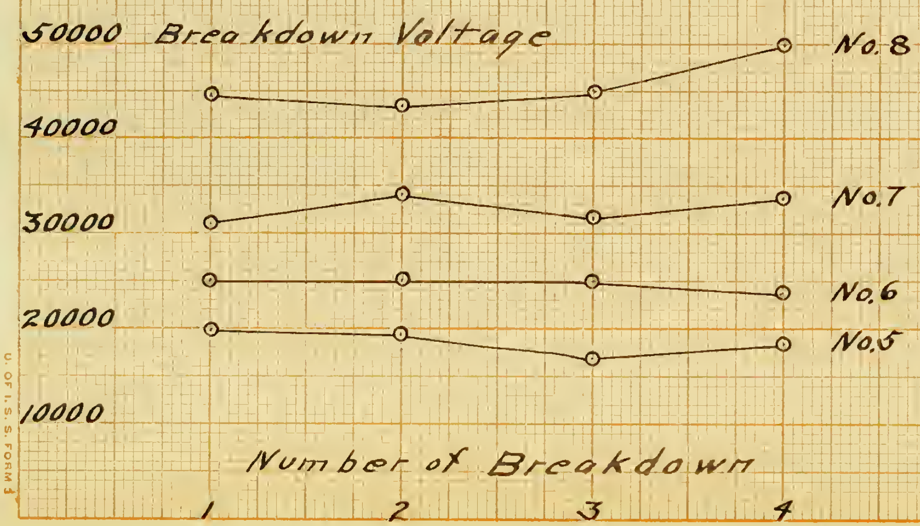
1/4" Rod
Brass Terminals
1/2"
2 1/2"
Test No IV
Kerosene from Trans.
E = 60000
Test No III
Transil Oil #6
E = 40000 Volts
Terminals:-
1/2" Balls on 1/4" rods.
Curve Shee No -III-
Gap in inches
.35
.30
.25
.20
.15
.10
.05
Number of Breakdown
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

Breakdown Tests
on
G.E. Transil Oil #6
Showing Effect
of
Condition of Terminal
on
Breakdown Voltage
Gap = .25 in.

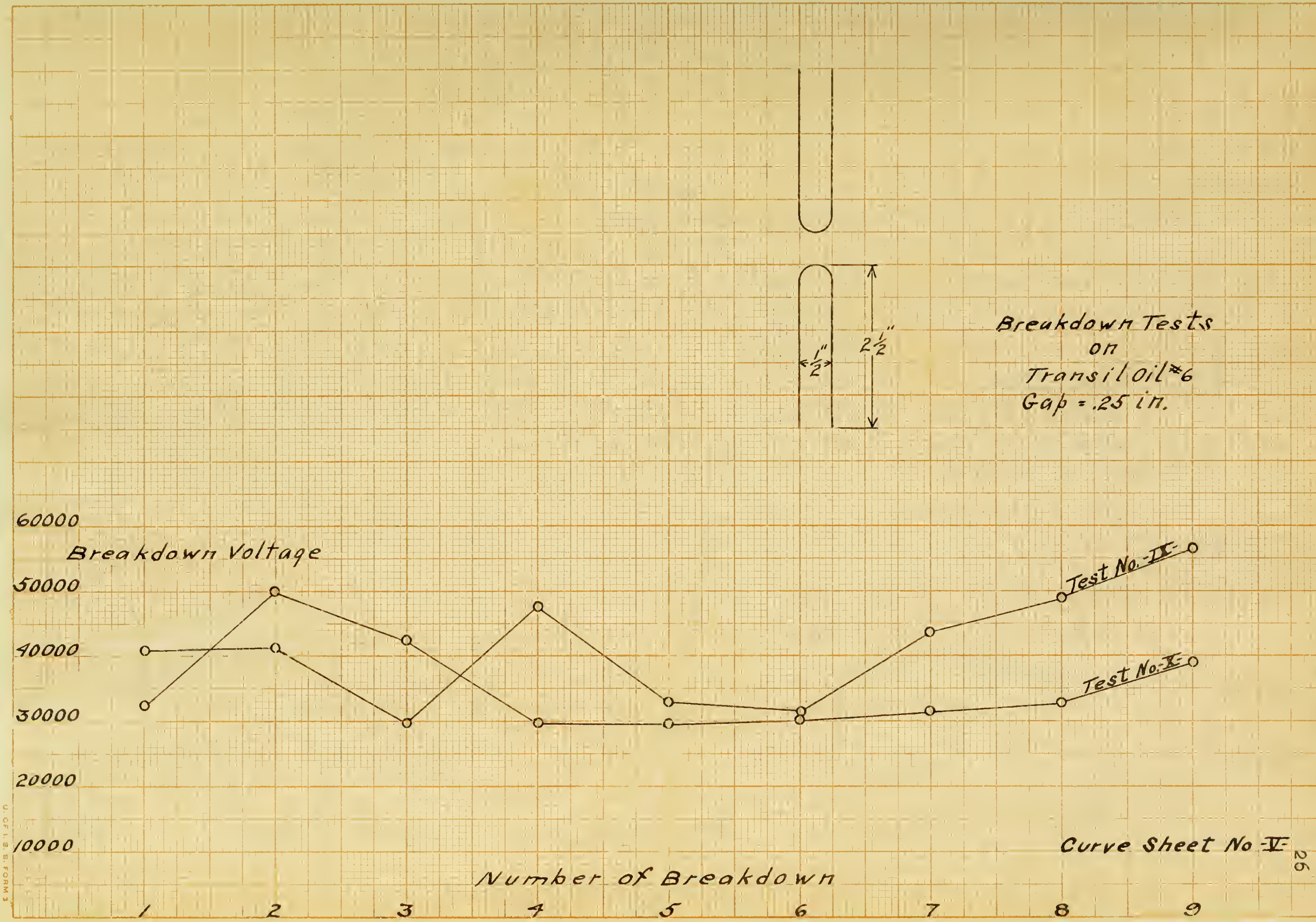
No. 5 Terminal: ½" Ball on 7/32" Rod - Loose Contact.
No. 6 Terminal: ½" Ball on 7/32" Rod - Tight Contact.
No. 7 Terminal: ½" Ball on ¼" Rod - Tight Contact.
No 8 Terminal: ½" Ball on 9/32" Rod - Tight Contact.

Note:

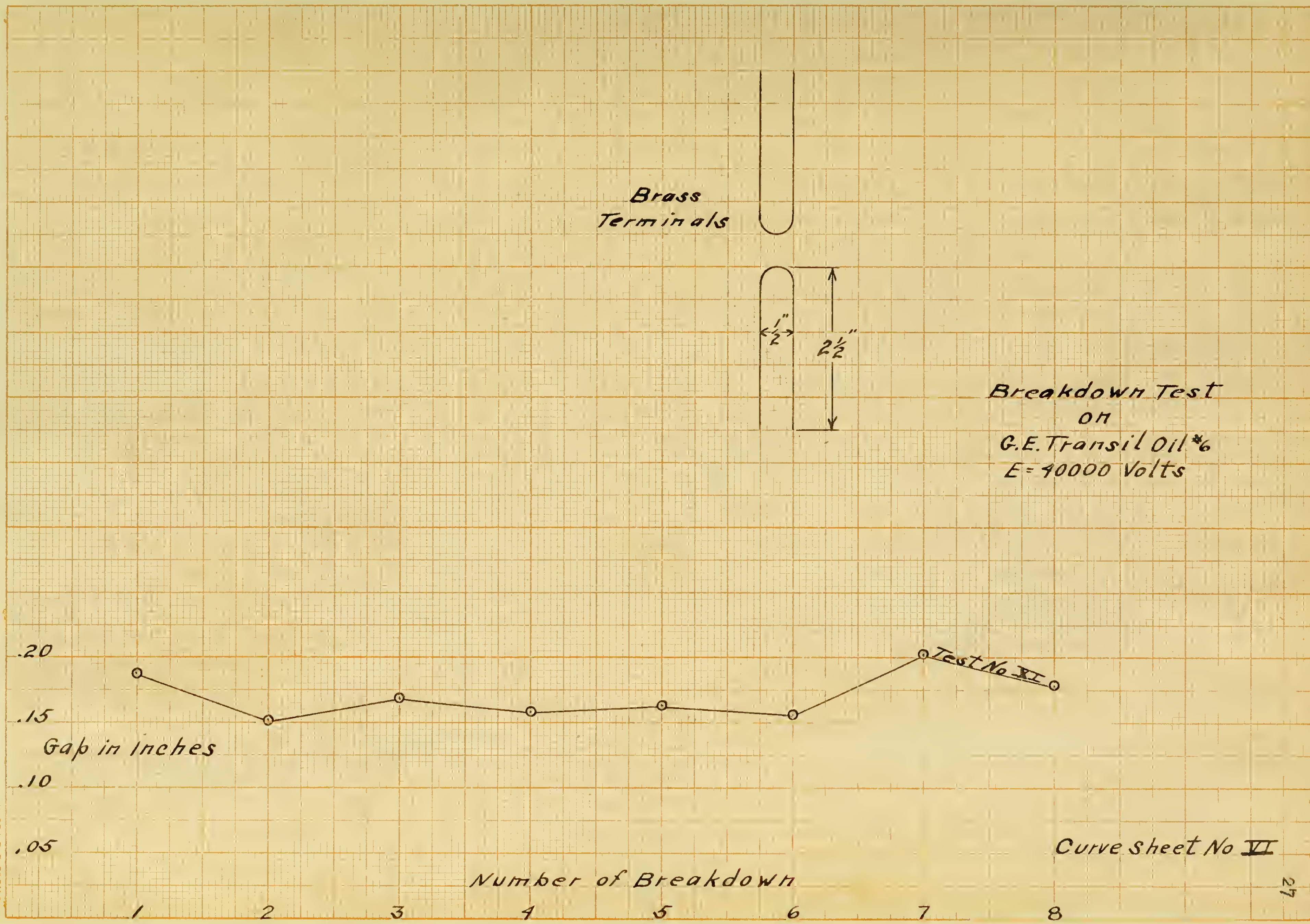
Upper Terminal was ½" Ball on ¼" Rod in all cases, the lower Terminal only being changed.

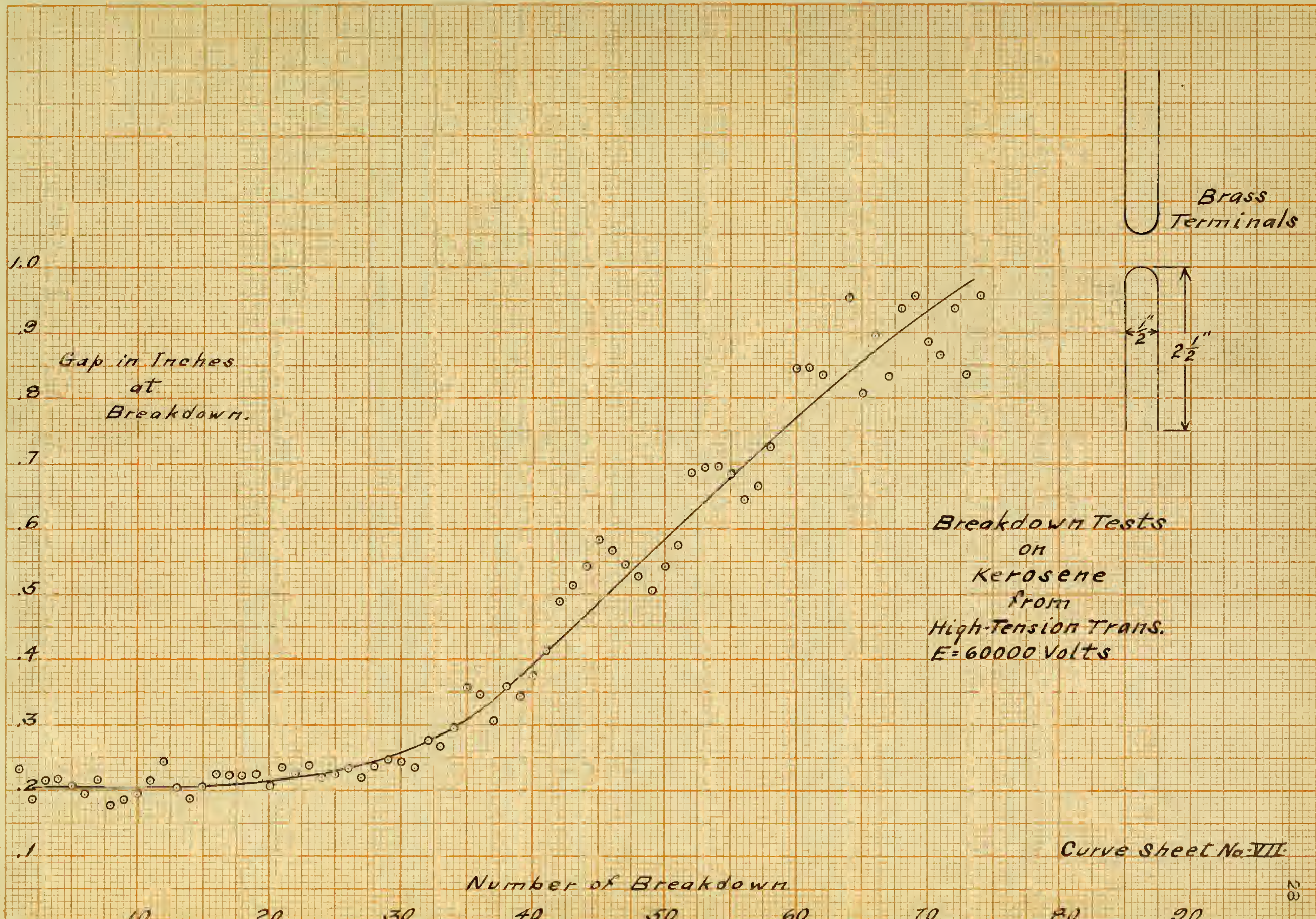


Curve Sheet No - IV -

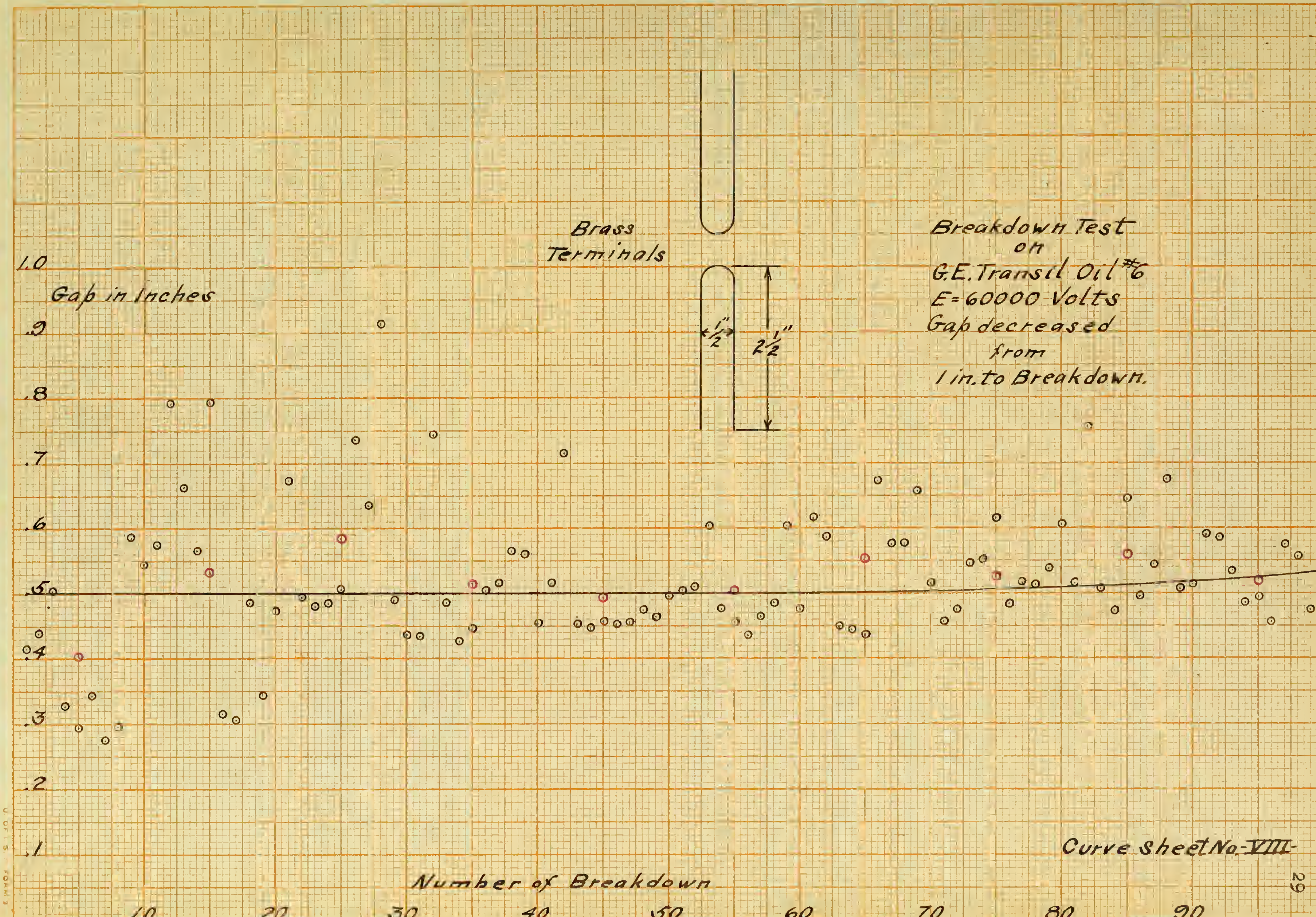


Curve Sheet No.-V-


Brass
Terminals
1/2"
2 1/2"
Breakdown Test
on
G.E. Transil Oil #6
E = 40000 Volts
Test No XI
.20
.15
Gap in Inches
.10
.05
Curve Sheet No VI
Number of Breakdown
1
2
3
4
5
6
7
8



Curve Sheet No. VII.


Brass
Terminals
1/2"
2 1/2"
Breakdown Test
on
G.E. Transil Oil #6
E=60000 Volts
Gap decreased
from
1 in. to Breakdown.
Gap in Inches
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
Number of Breakdown
10
20
30
40
50
60
70
80
90
Curve Sheet No.-VIII-